DOCUMENT RESUME

ED 449 027 SE 064 480

AUTHOR	Zeidler, Dana L.; Sadler, Troy D.
TITLE	Bad Science and Its Social Implications: Historical Perspectives.
PUB DATE	2000-10-00
NOTE	23p.; Paper presented at the Annual Meeting of the Southeastern Association for the Education of Teachers in Science (Auburn, AL, October 2000).
PUB TYPE	Opinion Papers (120) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Cultural Influences; Curriculum Development; Fraud; *Science and Society; *Science History; Secondary Education; *Social Studies
IDENTIFIERS	*Science Technology Relationship

ABSTRACT

This paper inquires into the topic of bad science and its social implications by examining selected issues aimed at elucidating some of the brute facts of scientific progress. It should be noted that the paper is also situated in at least 3 of the 10 overarching thematic strands that form the basis of the societal studies standards: cultural issues; power; authority; governance issues; and science, technology, and society issues. (Contains 37 references.) (SAH)

Reproductions supplied by EDRS are the best that can be made
from the original document.

ED 449 027

Bad Science and Its Social Implications: Historical Perspectives

Dana L. Zeidler

Troy D. Sadler

D Zeidler

Department of Secondary Education

College of Education

University of South Florida

Tampa, Florida 33620-5650

Email: Zeidler@tempest.coedu.usf.edu

Phone: (813) 974-7305

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Paper Presented at the Annual Meeting of the Southeastern Association for the Education of Teachers in Science, Auburn, Alabama, October, 2000.

SE 064 480

BEST COPY AVAILABLE

Introduction

The impact that science has had on society can not be overstated. The social fact that science has lead to the acceptance of specific epistemological and methodological belief systems – or social paradigms of thought as it relates to research traditions has been well described in the literature (Giere, 1988; Gould, 1995; Gould, 1996; Kuhn, 1970; Lakatos & Musgrave, 1970; Lakatos, 1978; Laudan, 1977). Students tend to view science as a monolithic authority lulled into accepting the power of its authority because of its firm foothold in the established traditions of its past successes, and because science has become interwoven into the fabric of our daily lives. Science epitomizes knowledge – and what school-aged child has not heard the catchall phase drummed into their psyche by good intentioned educators -- that "knowledge is power!"? Threats, browbeating, propaganda and ostracism ("get with the program!") are ways of exercising power. But power is exercised most efficiently when people conform to power because they fear not the penalty itself, but the potential to enforce it – the "power of suggestion!" That science tends to be seen as a foremost authority suggests to unwitting students (and many adults) that whatever knowledge is generated by the scientific enterprise must have importance and therefore that knowledge (or its utility) must be good.

Unfortunately, our schools are often not much help in allowing students to seek connections among disciplines because science is delivered (and therefore viewed) as a discrete body of knowledge apart from the period that social studies is taught, which is separate from language arts, and mathematics, etc.). This paper argues for an examination of topics that co-join social studies and science: bad science and its social implications. The importance of implementing curricula and strategies that help to empower students in

understanding their own social situation by providing opportunities in their educational experiences to care, question, and understand through inquiry has been advocated by others (American Association for the Advancement of Science, 1993; National Council for the Social Studies, 1994; National Research Council, 1996; Ross, 2000; Zeidler, 1984, 1997; Zeidler & Duplass, 2000). In addition to the well-known goals of the science education community, the National Council for the Social Studies (NCSS, 1994) has identified specific reasoning skills aimed at promoting better decision-makers and thinkers which include: acquiring information and manipulating data; developing and presenting policies, arguments, and stories; constructing new knowledge; and participating in groups (1994, pp. 7-8). This article provides an inquiry into the topic of bad science and its social implication and by examining selected issues aimed at elucidating some of the brute facts of scientific "progress." It should be noted that the present paper is also situated in at least three of the ten overarching thematic strands that form the basis of the social studies standards: Cultural Issues; Power, Authority, and Governance Issues; and Science, Technology and Society (STS) Issues.

In an effort to highlight these thematic strands, three areas of bad science (Cultural Prejudice Based on Scientific Errors, Unethical Science by Business and Government, and Unwitting Errors) were identified from the 19th and 20th centuries that cracked the pillars of established science and its institutional authority. Specific cases were selected because of the magnitude their impact had on the collective morality of our lives in terms of how we view culture, accept power and authority (and hence, governance), and are impacted by the interdependence of science, technology, and society. The cases have also been selected because of their pedagogical potential in

developing critical reasoning skills (see comments above), stimulating discussion and lending themselves to critical inquiry. In each case a description of the salient features surrounding the event is presented, a discussion of the basic error committed entailing some form of purposeful or unwitting fallacious reasoning (which we operationalize for the purposes of this article as "bad science") is described, and the social impact such errors in reasoning have on our personal, social or political beliefs is addressed.

Cracks in the Pillars

Cultural Prejudice Based on Scientific Errors

Case: Polygenism and Craniology.

There have been numerous cases where cultural biases impacted the scientific enterprise and the community of science produced results that (not surprisingly) reflected and confirmed the prevailing Zeitgeist. Scientific theories tend to be "contextualized"; i.e. consistent with the prevailing norms of both the scientific community and those of the greater society (Kuhn, 1970; Harding, 1993; Hubbard, 1990). Political agendas that fuse science with political and economic power have clearly been identified in contemporary literature (Callon, 1995; Cozzens, 1990; Gieryn, 1995). However, the case of phrenology offers simultaneously historical and contemporary lessons that are both illustrative and instructive in terms of understanding sociological factors that may lead to bad science.

The notion that overt appearances in body type, facial and cranial features (craniology) and even body adornment (i.e. tattoos) are directly linked to race, criminal temperament and intelligence are all by-products of the "science" of phrenology. The impetus of phrenology can be traced to the late 19th century and the turn of the 20th century when advocates such as Cesare Lombroso Bernard Hollander and Paul Bouts

advanced core "scientific" ideas. Arguably, it was Lombroso's scientific study and political discourse (1895, 1911) that had the most impact on producing cultural biases inasmuch as its base of support was built upon evolutionary theory and anthropometric data consisting of objectively measured body features. Since phrenology stressed precise quantitative measurements of facial features, it was deemed as an objective science and political decisions to oppress individuals, groups or cultures were implemented and justified based on objectivity and data-driven information. It was, for example, used by the British to justify their racial policies in the colonization of black tribes of Africa and in their dominance over the Irish. In this case, measurements of the jaw in relation to the mandible were said to be more similar to apes, monkeys or Cro-Magnon humanoids than to Anglo-Saxon people of Europe and thus constituted "inferior races." Extensions of phrenology included measuring convicted criminals' crania and body features to build a profile of innate social deviant characteristics. That some convicted murderers had pronounced jaws and pickpockets long hands and scanty beards provided a sufficient profile to convict others charged with similar offences well into the 1930's. Even more startling, since Lombroso's "anthropometric data" of criminal traits held the status of an evolutionary theory, heredity and criminal destiny were causally linked; hence, people could be convicted of crimes independent of evidence as long as their anatomy fit particular taxonomies of innate criminal anthropological traits as in the case of describing the "prehensile" foot features of prostitutes revealing atavistic anomalies. Another "quantitative" study of criminal tattoos further revealed genetic destiny: Lombroso formed typologies of criminals based on the content of the tattoos. Typologies were subsequently formed that coded criminals into groups like "lawless" or "unlucky." One

can only imagine how a tattoo that read "Long live France and french fried potatoes" was used to code for atavistic traits (Gould, 1996, p.162)! Similar scientific classifications based upon evidence of Aryan and non-Aryan features (or possessing degrees of Aryan or non-Aryan blood from mixed marriages) were used by anthropologists sympathetic to Nazi politics to segregate out those individuals from the population that would be relegated to death camps. (Gould, 1995) Infuse bad science with systemic anti-Semitism (Nazi) education (including curriculum chapters like: "The heredity of physical and spiritual characteristics of the German race; Sorting out people [Jews] plagued with hereditary diseases; Keeping the blood pure"), and an authority is doubly reinforced to advance doctrine and laws for the "racial health" and survival of their people (Wegner, 1991, p.198). Racist policies become more palatable to a given culture if the oppressed are viewed as "something" less than human.

It is tempting to view phrenology (and its related forms) as an interesting but anachronistic phase in the evolution of scientific knowledge. However, one only has to survey current literature (Colbert, 1997; Cooper & Cooper, 1983; Cooper & Childs, 1997; Hedderly, 1970; Leek, 1970) and Internet sites (e.g. http://134.184.33.110/phreno/kritiek.html and http://134.184.33.110/phreno/faculty.html) to realize that such practices are still advocated in the name of "true science." With the aid of a phrenology chart, a practitioner can ascertain personality traits from observing, measuring or reading the shape of the bumps, ridges, and bones of the subject's head. *Benevolence*, for example, is said to be located in the upper part of the forehead which is found to be convex where benevolence is strong or slanted where it is lacking. The more obvious protuberances are located halfway on the forehead, the greater the capacity for

causality (abstract, logical thinking) exists. And so it goes for other faculties such as *perception*, *morality*, *destructiveness*, *firmness*, *constructiveness*, *veneration*, *hope*, etc. Modern proponents of this science have attempted to gussy it up by distancing it from a checkered past and suggest it can be used to serve humanity. "New age" advocates of phrenology claim that human resource management counselors may help direct people into their proper fields inasmuch as particular arts or trades (e.g. law, medicine, divinity, journalism, mechanical arts, fine arts, etc.) demand requisite skills that can be matched to genetically endowed personality traits all determined by phrenological methods. In other words, phrenology can predict whether an individual will succeed in a given profession:

> Clergymen require the mental temperament, to give them a decided predominance of Mind over their animal propensities; a large frontal and coronal region, the former to give them intellectual capacity, and the latter to impart high moral worth, aims and feelings, elevation of character, and blamelessness of conduct; large *Veneration*, *Hope* and *Spirituality*, to imbue them with the spirit of faith and devotion; large *Benevolence* and *Adhesiveness*, so that they make all who know them love them, and thus win each other over the paths of truth and righteousness. Clergymen do well to consult Phrenology; it would enable them to account for many seeming mysteries, and give them power and influence to do great good. ... These statements are of course also largely applicable to non-confessional moral counselors.
>
> (Van den Bossche, (2000), http://134.184.110/phreno/professions.html)

It is comforting to know that contemporary phrenological practitioners recognized that subject errors of interpretation might occur in the "diagnosis" of clients if the phrenological examination of the skull is incomplete or the observer is misled by the subject's hairstyle!

The basic errors of phrenology and craniology stem from a combination of fallacious reasoning and incomplete attention to disconfirming evidence. In the case of contemporary phrenology, it is easy to detect the ill-fated logic in the form of circular reasoning of the following premise:

> Starting from the measurements made on a subject's skull, it is possible to state which character faculties are more or less developed. The combination of these faculties yields an overview of the subject's character and personality. These are the innate propensities of the subject, the real foundations of the personality, which may be adjusted but not changed by external factors like environment and education. ... Phrenological analysis describes a person's naked body, external factors provide the clothes, which, even when influencing exterior appearance, will never change the body itself.
>
> Van den Bossche. (2000), http://134.184.33.110/phreno/kritiek.html)

That measurements of a subject's skull are equated with innate personality characteristics (the premise) which reveal innate propensities of the subject (the warrant) indicate the "real" foundations of personality (the conclusion) is a fallacious argument, The conclusion is already contained within the premise (and in this case the warrant too) providing a circular argument.

Whether used to weed out inferior races, identify moral character flaws, or counsel individuals into the proper fields that best suit their genetic endowment, those who practice phrenology and its related offshoots evoke the power of quantification and objectivity and use their methods implicitly or explicitly as a form of social control. Phrenology's appeal to (pseudo)scientific techniques advanced cultural stereotypes and prejudices under a deterministic view of human behavior. In present day, one still finds conventional racism dressed in the regalia of scientific authorities.

Unethical Science by Business and Government

Case: Big Tobacco.

Starting in the late 1920's, when biological and health researchers began investigating the effects of tobacco, early conclusions suggested high toxicity. One researcher employed by the industry gauged toxicity by placing tobacco-smoke extract on rabbits' eyes. He terminated the experiment prematurely because a single drop was potent enough to cause immediate sores and the eventual loss of the entire eye. In a report that landed on several executives' desks, the scientist claimed that tobacco was the most toxic substance he had ever seen. In 1953, a research group from the Sloan Kettering Institute published a report describing the formation of cancerous tumors on the skin of mice exposed to cigarette smoke condensate. In an unpublicized meeting, top executives from the major tobacco companies (Philip Morris, R.J. Reynolds, Brown and Williamson, American Tobacco, U.S. Tobacco, and Benson and Hedges) met to address the attacks against their industry and affirm they could produce "comprehensive and authoritative scientific material which completely refutes the health charges" (Hilts,

1996, p.6). A plan emerged from the meeting for the industry to invest large sums of money to prevent scientists and public health officials from discouraging cigarette usage.

The industry sought scientists sympathetic to their cause and new mission. They awarded research grants to scientists investigating alternative cancer causation. Great efforts were made to only sponsor research that could not produce damaging information, but undesirable results emerged. The industry began reviewing, and if necessary, censoring scientific reports prior to publication. Many experiments were simply buried so that their findings would never reach the public. In a confidential report, an industry scientist wrote, "There are biologically active materials present in cigarette tobacco. These are a) cancer causing b) cancer promoting c) poisonous d) stimulating, pleasurable, and flavorful (Hilts, 1996, p.25)." Damaging research, linking tobacco to many types of cancer, coronary diseases, and pulmonary problems, continued to mount throughout the 1960's and 70's. Recognizing that the "authoritative scientific material" sought by the industry did not exist, industry-funded labs charged with proving that tobacco was safe began closing down in the 70's and 80's (Hilts, 1996).

It is also interesting to note in the 1960's, tobacco companies began investigating the active agent in cigarettes: nicotine. Industry scientists quickly showed that nicotine is addictive and without nicotine the industry would crumble. Executives continued to claim that nicotine's sole purpose in a cigarette is to add taste; however, the research and manufacturing processes revealed a different story. Companies used specific tobacco blending protocols in order to ensure nicotine content. They also added ammonia which doubles the amount of nicotine ingested, because it frees chemically-bound nicotine that otherwise would not be available to the smoker. Publicly, the industry reported that

nicotine content is a function of the tobacco leaves used in manufacturing. However, informants claimed that companies monitor and control the amount of nicotine in their cigarettes by adding nicotine during the manufacturing process. Philip Morris documents indicate that nicotine content on production lines is determined hourly and if necessary, nicotine extract is added. Some companies went so far as to study psychological profiles and nicotine affinity in order to design cigarettes that met the "nicotine needs" of customers (and potential customers) (Glant, Slade, Bero, Hanauer & Barnes, 1996; Hilts, 1996).

Many individuals find the story of Big Tobacco distasteful if not appalling, but why is this bad science? The industry has misused science in an attempt to prove the efficacy of its product when the data clearly showed that its product was dangerous. It then concealed but used information gained through science to prey on an unsuspecting public. One only has to refer to popular magazines from the 1940's and 50's to find evidence of ad campaigns by big tobacco to appeal to (scientific) authority in an effort to convey that our nations most educated and trusted leaders wholly endorse the use of tobacco products. Consider, for example, the following advertisement the R.J. Reynolds Tobacco Company ran in LIFE Magazine that portrayed a Norman Rockwellian-like scene with a smiling family doctor standing on a sidewalk by a white picket fence lined with flowering shrubs, dressed in a white suit, white fedora, wire-rimmed glasses, black bow tie, medical bag in tow reaching out to greet and pat on the head a dimple-faced little boy, his dog and approving mother. The following words accompany this heart-warming, slice of American-Pie scene:

> The doctor makes his rounds: Where he goes, he is welcome ... his life is dedicated to serving others. Not all his calls are associated with illness. He is often friend and counselor...he is present when life begins, watches it flourish and develop. His satisfactions in life are reflected in the smiling faces of youngsters like this one [in the ad] below, and of countless others whom he has long attended. Yes, the doctor represents an honored profession...his reputation and his record of service are cherished possessions. ... *According to a recent Nationwide survey, MORE DOCTORS SMOKE CAMELS THAN ANY OTHER CIGARETTE* ... If you're a Camel smoker, this definite preference for Camels among physicians will not surprise you. If not, then by all means try Camels. Try them for taste ... for your throat. That's the 'T-Zone' test. ... For only *your* taste and *your* throat can decide which cigarette tastes best to *you*...and how it affects *your* throat. (LIFE, August 19, 1946, p.39)

In 1994, Philip Morris ran a full page newspaper ad making the following claim: "A large U.S. study published in the *American Journal of Public Health,* found no overall statistically significant link between second-hand smoke and lung cancer" (Hilts, 1996, p.106). In fact, the article claimed a small but significant increase in the incidence of lung cancer due to second-hand smoke. For many public observers, "scientific claims" carry merit just because they are "scientific." Therefore, individuals making claims under the auspices of science should adhere to one of its central tenets: full disclosure. Deception continued as tobacco spokespeople denied health risks associated with smoking despite overwhelming evidence produced in their own labs. Tobacco companies

not only lied to the public, they used the information about the potency of nicotine to create "scientifically" sanctioned addiction. Presenting partial truths or complete inaccuracies is a violation of scientific ethics. Big tobacco used the name science to give their propaganda instant value without adhering to the guidelines of the scientific enterprise.

The consequences of such unethical science have lead to approximately 48 million adult smokers in the US. Between 1990 and 1994, cigarettes caused the death of 430,700 people. One out of every 5 deaths in the country was a cigarette-related death. Males that smoke are 23 times more likely to contract lung cancer than non-smokers and female smokers are 13 times more susceptible to cancer (American Cancer Society). Smoking also contributes to cancers of the mouth, throat, reproductive and urinary systems as well as a litany of cardiovascular and pulmonary diseases (Hilts, 1996). From an economic vantage, the tobacco industry has been equally devastating. It is estimated that health costs and loss of productivity drain $100 billion from the US economy. Big Tobacco has made billions of dollars by misrepresenting scientific information influencing public opinion as well as governmental policy. As the industry has profited, the American people have paid the price in human lives and health care dollars.

Unwitting Errors: Errare humanum est

Case: Exotic Species.

Any plant, animal or microorganism living in a place that it does not naturally occur is an exotic species. Humans aid the dispersal of exotics across natural barriers and/or promote their establishment by creating favorable conditions for growth and reproduction. In many cases humans have been unknowing accomplices; live specimens,

seeds or eggs get transported across barriers in ship ballast water or food products and other imports. Some exotic infestations have been clearly inadvertent such as flushing a pet fish from Africa in a sewer system that eventually leads to one of the Great Lakes. However, several exotic species have been intentionally released into foreign environments for ecological purposes. Typically, the releasers are authority figures such as government agencies that, with or without the aid of scientists, embark on a biological experiment.

While there are numerous examples of intentionally introduced exotics (e.g. kudzu, tamarisk, purple loosestrife, rosy wolf snail), the case of melaleuca serves to illustrate the environmental and social impacts. At the turn of the twentieth century melaleuca, also known as "paper-bark tree," was imported to Florida for ornamental purposes. Melaleuca is a tree native to Australia and New Guinea that can grow up to 100 feet and sheets of white, spongy bark cover its trunk and stems. Mature trees consume and transpire enormous amounts of water so in the 1930's officials liberally scattered seeds to "drain swampland." Aerial spreading and rapid growth rates aided the species' establishment throughout the Everglades and other Florida wetlands (Langeland & Burks, 1998).

Two errors were made in the introduction and distribution of melaleuca. Whenever something is put into or removed from an environment in large enough concentrations, large-scale alterations usually follow. Exotics can often out-compete native species because the invaders do not have natural predators, parasites and diseases with which to contend. When melaleuca was introduced, it possessed properties that enabled it to exploit the environment differently from native plants. Native plants lack

the time needed to evolve adaptations to successfully compete. As the exotics displaced the natives, all organisms dependent and ecologically related were also affected.

The other mistake was a misunderstanding of natural ecosystems' roles. When melaleuca was broadcast across Florida, the general public and scientists equated wetlands with wastelands. Land covered in standing water could not be used for building, farming or recreation, so people sought ways to convert wetlands into dry lands. After "swamp drying" had begun employing biological agents and canals, ecologists realized the environmental significance of wetlands. Wetlands ensure the health of the surrounding physical environments by filtering toxins, preventing erosion, cleaning fresh water and absorbing floodwater. Wetlands are also crucial to wildlife: migratory birds use marshes as stopover points; birds, reptiles, mammals and fish (including economically important species) breed and rear offspring in wetlands; and nutrients stored in wetlands impact a multitude of food webs. The scientific community now knows that swamps once deemed useless are actually vital.

By 1994 melaleuca infested 500,000 acres in South Florida. In at least 26,000 acres, 95% or more of the trees present are melaleuca. Natural communities in the Everglades support several tree species creating a mosaic inhabited by hundreds, perhaps thousands, of other organisms. Monolithic stands prove deadly not only for the trees that were displaced but also ground plants which do not receive enough light through the dense canopy and animals which are not suited to exploit the trees themselves (Cox, 1999). Those responsible for spreading the exotic correctly surmised that it would dry swamps. Melaleuca has altered Florida's hydrology and compromised wetland areas, because it absorbs much more water than native trees and releases most of it into the

atmosphere. We cannot assess the final consequences because the "experiment" continues. No one has been able to stop or even slow the spread of melaleuca once it had become established. The Everglades have been altered by other factors as well including canal digging, agricultural runoff, and residential development. The combined effects of these factors and melaleuca have prompted the federal government and the state of Florida to spend hundreds of millions of dollars on wetland restoration. Between 1994 and 1999, the Everglades Trust Fund which drew federal and state money, spent over $330 million on ecosystem restoration (www.sfwmd.gov). The economic and environmental costs of this shortsighted scientific mishap will certainly increase as melaleuca continues to destroy natural habitats.

Conclusions and Implications for Science Teaching

Science suffers from a Jeckyl and Hyde affliction; the discipline possesses two radically different faces. In one respect, reminiscent of the affable doctor, science penetrates and improves nearly all aspects of society. The modern conveniences we enjoy, the medical breakthroughs that save our lives, the technology that solves our crimes are just a few of the many ways that science edifies our world. However, if the scientific community vocally maintains its role in improving society, then it must also garner the courage to illuminate its own shortcomings. Our collective history is dotted with episodes in which the pillars of science not only cracked but also transmogrified into monsters of oppression, greed or misjudgment. Science educators have a responsibility to share not only the triumphs of their field but the failures as well. Unfortunately, many times scientists and teachers of science fall short of their mark in displaying the true, sometimes schizophrenic, nature of science. One need look no farther than the vast

majority of science textbooks in use throughout our country. They are filled with hundreds of pages chronicling successful experiments, "proven" theories and philanthropic results. Seldom do textbooks reveal the mistakes, failures and cover-ups that have been just as much a part of the field as some of the more frequently mentioned feats. By not sharing the reality of bad science with our students, we deny the fact that science is a human enterprise. When we only recount the triumphs, we reinforce the monolithic authority that exists only in the perceptions of those whose views are limited or distorted. Incorporating examples of bad science and its social impact into science classrooms is one way of returning to the brute fact that that the activity of science has a human face.

Teaching about the intentional as well as the unwitting errors of science aligns with three different thematic strands (The Nature of Science, Human Society, and Historical Perspectives) of Project 2061 in addition to other content material that could be explored in the process (AAAS, 1989; 1993). Instruction in cases of "bad science" seems an ideal way to challenge student beliefs on the nature of science including its propensity to be certain or tentative, objective or subjective, value-free or value laden, amoral or moral, social or asocial. Handling cases like those mentioned in this paper provide ample opportunities to engage students in discussion, critical thinking and ethical decision making all of which, according to most educators, are some of the most important aspects of education. By incorporating the historical contexts of these cases, students are able to see explicit links between science and other fields that aid the association between classroom science and their own lives. One of science's greatest challenges is courting the populace; most people keep a healthy distance between themselves and the scientific

world. Munby (1976) noted the problem a quarter century ago and the issue has not disappeared. People revere the products of science but are intimidated by science itself. Munby attributed this attitude to the manner in which most people were exposed to science during their formal education. Science educators commit a disservice to their students and their discipline if they intentionally or unwittingly sterilize science, thereby divorcing the full range of human activity that exists in the scientific enterprise. Rather than just highlighting scientific products worthy of the ivory tower, we must begin discussing all of the byproducts. Science educators should seize the opportunity to deliver a new message, one that encourages participation by all, to their students: Science, like all human enterprises, is prone to make mistakes which often have dire societal consequences. If we expect our students to participate in a scientific world, then they must be prepared to deal with the social ramifications that are inextricably bound to the science itself.

References

American Association for the Advancement of Science, (1989). Project 2061: Science for all Americans. Author.

American Association for the Advancement of Science, (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Callon, M. (1995). Four models for the dynamics of science. In S. Jasanoff, G. Markle, J. Peterson, & T. Pinch (Eds.), *Handbook of science and technology studies*. Thousand Oaks, CA: Sage Publication, Inc.

Colbert, C. (1997). *A measure of perfection. Phrenology and the fine arts in America*. Chapel Hill: The University of North Carolina Press.

Cooper, H. & Cooper, P.(1983). *Heads, or the art of phrenology*. London: The London Phrenology Company Ltd.

Cooper, P. & Childs, K., (1997). *Phrenology : A guide*. London : The London Phrenology Company Ltd.

Cox, G. W. (1999). *Alien species in north America and Hawaii: Impacts on natural ecosystems*. Washington, DC: Island Press.

Cozzens, S.E. (1990). Autonomy and power in science. In S.E. Cozzens & T.F. Gieryn (Eds.), *Theories of science in society*. Bloomington: Indiana University Press.

Giere, R.N. (1988). *Explaining science: A cognitive approach*. Chicago: The University of Chicago Press.

Gieryn, T.F. (1995). Boundaries of science. In S. Jasanoff, G. Markle, J. Peterson, & T. Pinch (Eds.), *Handbook of science and technology studies*. Thousand Oaks, CA: Sage Publication, Inc.

Glantz, S.A.; Slade, J.; Bero, L.A.; Hanauer, P.; & Barnes, D.E. (1996). *The cigarette papers*. Berkley, CA: University of California Press.

Gould, S.J. (1995). *Dinosaur in a haystack: Reflections in natural history*. New York: Crown Trade Paperbacks.

Gould, S.J. (1996). *The mismeasure of man*. New York: W.W. Norton & Company.

Harding, S. (1993). Introduction. In S. Harding (Ed.), *The "racial" economy of science: Toward a democratic future*. Bloomington, IL: Indiana University Press.

Hedderly, F. (1970). *Phrenology: A study of mind*. London: L.N. Fowler and Co. Ltd.

Hilts, P.J. (1996). Smoke Screen: *The truth Behind the tobacco industry Cover-up*. Reading, MA: Addison Wesley.

Hubbard, R. (1990). *The politics of women's biology*. New Brunswick, NY : Rutgers University Press.

Kuhn, T.S. (1970). *The structure of scientific revolutions*. Chicago: The University of Chicago Press.

Lakatos, I. (1978). The methodology of scientific research programmes. Cambridge: Cambridge University Press.

Lakatos, I., & Musgrave, A. (1970). *Criticism and the growth of knowledge*. Cambridge: Cambridge University Press.

Langeland, K.A. & Burks, K.C. (1998). Identification and biology of non-native plants in Florida's natural areas. Gainesville, Fl: University of Florida.

Laudan, L. (1977). *Progress and its problems: Towards a theory of scientific growth.* Berkeley: University of California Press.

Leek, S. (1970). *Phrenology*. London: Collier-Macmillan Ltd.

LIFE, (1946). *Advertisement*, August 19, p. 39. Chicago: TIME, Inc.

Lombroso, C. (1895). Criminal anthropology applied to pedagogy. *Monist 6*, 50-59.

Lombroso, C. (1911). *Crime: Its causes and remedies*. Boston: Little, Brown.

Munby. H. (1976). Some implications of language in science education. *Science Education, 60*(1), 115-124.

National Council for the Social Studies, (1994). Expectations of excellence: Curriculum standards for social studies. Washington, DC: Author.

National Research Council, 1996. *National science education standards*. Washington, DC: National Academy Press.

Ross, E.W. (2000). Creating a civic-minded political culture: What does the civics NAEP mean for social studies education? *Theory & Research in Social Education, 28*(1), 6-10.

Van den Bossche, P. (2000). Criticisms against phrenology. Retrieved August 27, 2000 from the World Wide Web: http://134.184.110 phreno professions.html.

Van den Bossche, P. (2000). Phrenology and human resources. Retrieved August 27, 2000 from the World Wide Web: http://134.184.33.110 phreno/kritiek.html.

Wegner, G.P. (1991). Schooling for a new mythos: Race, anti-semitism and the curriculum materials of a Nazi race educator. *Paedagogica Historica 27*(2), 189-213).

Zeidler, D.L. (1984). Moral issues and social policy in science education: Closing the literacy gap. *Science Education, 68*(4), 411-419.

Zeidler, D.L. (1997). The central role of fallacious thinking in science education. *Science Education, 81*(4), 483-496.

Zeidler, D.L. & Duplass, J.A. (2000). Critical thinking and the role of logical argument in social studies education. *International Journal of Social Education,15*(1) (Fall) (In Press).